

CLAIMS

What is claimed is:

- 5 1. A method for selectively extracting one or more metal anion complex from an aqueous solution, the method comprising:
 contacting the aqueous solution with an organic solution including a diquaternary amine, wherein the diquaternary amine has two diquaternary nitrogens spaced at a distance of less than about 10 Å;
10 selectively binding the metal anion complex to the diquaternary amine; and then
 separating the organic solution from the aqueous solution, wherein the diquaternary amines having the selectively bound metal anions are concentrated in the organic solution.
- 15 2. The method of claim 1, wherein the one or more metal anion complex comprise one or more platinum group metals.
- 20 3. The method of claim 1, wherein the one or more metal anion complex are selected from anions of Pt, Pd, Rh, and combinations thereof.
- 25 4. The method of claim 1, wherein the aqueous solution comprises anions of one or more metals to be selectively extracted, and anions of contaminant metals.
5. The method of claim 4, wherein the contaminant metals are selected from the group consisting of Pb, Al, Ba, Ce, Zr, Fe, Cu, Co, Ni, Mo, Sn, Sb, As, Bi, Zn, Na, K, Ca and combinations thereof.

6. The method of claim 1, wherein the one or more metal anion complex comprise a metal selected from Ag, Au, Pd, Rh, Pt, Ru, Os, Ir, and combinations thereof.

7. The method of claim 1, wherein the distance between the two diquaternary nitrogens is
5 between about 5 Å less and 5 Å more than the size of the one or more metal anion complex to be selectively extracted.

SEARCHED
INDEXED
MAILED
FILED

8. The method of claim 1, wherein the distance between the two diquaternary nitrogens allows the formation of a complex between both diquaternary nitrogens and the one or more metal anion complex to be selectively extracted.

9. The method of claim 1, wherein the aqueous solution is acidic.

10. The method of claim 1, wherein the aqueous solution contains an acid selected from hydrochloric acid, sulfuric acid, nitric acid and combinations thereof.

11. The method of claim 9, wherein the diquaternary amines are characterized in that the diquaternary amines extract the one or more metal anion complex at all acid concentrations.

20 12. The method of claim 1, wherein the aqueous solution is contacted with the organic solution for a time period of less than about 30 minutes.

13. The method of claim 1, wherein the aqueous solution is contacted with the organic solution for a time period of less than about 20 minutes.

25 14. The method of claim 1, wherein the aqueous solution is contacted with the organic solution for a time period of between about 5 minutes and about 20 minutes.

15. The method of claim 1, wherein the concentration of the diquaternary amines within the organic solution is between about 10% and saturation.

5 16. The method of claim 1, wherein the concentration of the diquaternary amines within the organic solution is between about 0.5 % and about 10%.

17. The method of claim 1, wherein the concentration of the diquaternary amines within the organic solution are between about 0.5 % and about 6 %.

10 18. The method of claim 1, wherein the concentration of the diquaternary amines within the organic solution are between about 1 % and about 5 %.

15 19. The method of claim 1, wherein the organic solution has an organic solvent selected from chloroform, 1-octanol, methanol, and combinations thereof.

20. The method of claim 1, wherein the organic solution has any of one or more water immiscible organic solvents in which the diquaternary amines are soluble.

20 21. The method of claim 1, wherein the diquaternary amine is a diquaternary ammonium halide that is essentially insoluble in water.

22. The method of claim 1, wherein the two diquaternary nitrogens are separated by an alkyl chain.

25

23. The method of claim 22, wherein the alkyl chain is saturated.

24. The method of claim 22, wherein the alkyl chain is unsaturated.
25. The method of claim 22, wherein the alkyl chain is straight.
- 5 26. The method of claim 22, wherein the alkyl chain is branched.
27. The method of claim 1, wherein the two diquaternary nitrogens are linked in a heterocyclic ring structure.
- 10 28. The method of claim 27, wherein the ring structure is saturated.
29. The method of claim 27, wherein the ring structure is unsaturated.
30. The method of claim 27, wherein the ring structure is straight.
- 15 31. The method of claim 27, wherein the ring structure is branched.
32. The method of claim 21, wherein the diquaternary ammonium halide comprises a halogen selected from iodine and chlorine.
- 20 33. The method of claim 21, wherein the diquaternary ammonium halide comprises a halogen selected from bromine and fluorine.
- 25 34. The method of claim 1, wherein the one or more metal anion complex comprises a metal selected from Pd, Pt, Rh and combinations thereof, and wherein the two diquaternary nitrogens are separated by an alkyl chain having 2 to 8 carbon atoms.

35. The method of claim 1, wherein the one or more metal anion complex comprises a metal selected from Pd, Pt, Rh and combinations thereof, and wherein the two diquaternary nitrogens are separated by an alkyl chain having 2 to 6 carbon atoms.
- 5 36. The method of claim 1, wherein the one or more metal anion complex comprises a metal selected from Pd, Pt, Rh and combinations thereof, and wherein the two diquaternary nitrogens are separated by an alkyl chain having 2 to 3 carbon atoms.
37. The method of claim 34, wherein the diquaternary ammonium halide is a chloride.
- 10 38. The method of claim 34, wherein the diquaternary ammonium halide is an iodide.
- 15 39. The method of claim 1, wherein the one or more metal anion complex comprises a metal selected from Pd, Pt, Rh and combinations thereof, and wherein the two diquaternary nitrogens are part of a heterocyclic ring structure having 2 to 8 carbon atoms.
40. The method of claim 39, wherein the diquaternary ammonium halide is selected from a chloride, an iodide, and combinations thereof.
- 20 41. A method for recovering Pd and Pt metals from a spent catalyst comprising:
dissolving the metals into an acidic solution to form metal anion complexes;
contacting the acidic solution with an iodide;
separating the iodide from the acidic solution, wherein the Pd anion complex is bound to the iodide;
- 25 contacting the acidic solution with an organic solution including a diquaternary amine, wherein the distance between two diquaternary nitrogens is less than about 10 Å;
selectively binding the Pt anion complex to the diquaternary amine; and

separating the organic solution from the aqueous solution, wherein the diquaternary amines having the bound Pt anion complex are concentrated in the organic solution.

42. The method of claim 41, wherein the acidic solution contains acids selected from
5 hydrochloric acid, sulfuric acid, nitric acid and combinations thereof.
43. The method of claim 41, wherein the iodide is selected from potassium iodide, sodium iodide, magnesium iodide, calcium iodide and combinations thereof.
- 10 44. The method of claim 41, wherein the iodide is an organic iodide.
45. The method of claim 41, wherein the iodide is an inorganic iodide.
- 15 46. A method for recovering palladium from an aqueous solution, comprising:
contacting the aqueous solution with an iodide and an organic solvent;
allowing the palladium to bind to the iodide; and then
separating the organic solution from the aqueous solution, wherein the iodide having the
bound palladium ions are concentrated in the organic solution.
- 20 47. A method for selectively extracting one or more metal anion complex from an aqueous
solution, the method comprising:
contacting the aqueous solution with a diquaternary amine, wherein the distance between
two diquaternary nitrogens is less than about 10 Å;
binding the one or more metal anion complex to the diquaternary amine; and then
25 separating the diquaternary amine from the aqueous solution, wherein the diquaternary
amine is bound to a solid surface of an inert substrate.

48. The method of claim 47, wherein the one or more metal anion complex comprises one or more platinum group metals.

49. The method of claim 47, wherein the diquaternary amines are bound to a solid surface by 5 means selected from adsorption and chemical bonding.

50. The method of claim 47, wherein the inert substrate is a polymer.

51. A method for recovering valuable metals comprising:

510 a. dissolving the metals into an acidic solution;

b. contacting the acidic solution with an iodide;

c. separating the iodide from the acidic solution, wherein Pd is bound to the iodide;

515 d. contacting the acidic solution with a first organic solution including a first diquaternary amine, wherein the distance between two diquaternary nitrogens is less than about 10 Å and wherein the first diquaternary amine is a selective extractant for a second valuable metal;

e. selectively binding the second valuable metal anions to the first diquaternary amine; and then

20 f. separating the organic solution from the aqueous solution, wherein the first diquaternary amine has the selectively bound second valuable metal anions concentrated in the organic solution.

g. repeating steps d through f, using a second diquaternary amine to selectively extract a third valuable metal.